

2.2 *Thermal Considerations*

2.2.1 Thermal Design Requirements

The Hitchhiker carrier and customer equipment relies primarily on a passive thermal design consisting of multilayer insulating blankets (MLI) and selected surface-finish applications. The MLI will be used to reduce energy losses and gains from the environment. Thermostatically controlled heaters will be used where tighter thermal control is needed, and passive radiators will be used to dump excess heat from instruments. This cold-bias design philosophy incorporates a low cost approach to maintaining temperature requirements throughout the HH payload.

The thermal design and analysis of each experiment is a customer responsibility. The customer shall determine all internal conduction, convection, and radiation within their experiment. They shall be responsible for the proper design and coupling of high power components. Reduced thermal models of the experiment and associated electronics are to be supplied to HH. Temperature limits as defined below shall also be provided for each node in the reduced thermal math model.

Operating Temperature: The temperature at which a unit will successfully function and meet all specifications.

Non-Operating Temperature: The temperature to which a unit may be exposed in a power OFF condition and if turned ON, will not be damaged. The unit does not have to meet its specification until it is within the operational temperature range.

Survival Temperature: The temperature, if exceeded, at which the unit will suffer permanent damage.

Safety Temperature: The temperature, if exceeded, at which the unit could potentially lead to catastrophic damage to the orbiter or injury to the crew members.

The customer shall also define any special temperature requirements, such as levels and gradients. Ground temperatures and humidity provided by the Orbiter and other ground processing locations at KSC are defined in ICD2-19001.

A list of the following external surface properties: area (size), thermal coatings, absorptivity (α), emissivity (ϵ), and reflectivity shall be provided. The customer will be responsible for obtaining approval from GSFC regarding any proposed thermal coatings not standard to HH. They shall also be responsible for providing heaters on the experiment provided hardware. The heater specification along with the predicted dissipation, duty cycle and HH bus usage shall be supplied to HH.

2.2.2 Thermal Safety Requirements

The customer must also be aware of all safety concerns of their payloads including that the experiment must be safe without services i.e. remain safe in the event of a power loss. Payloads must also be safe to land 40 minutes after payload bay door closure, occurring anytime during the mission. In addition to all safety analysis, all payloads must be able to fly in a bay-to-Earth attitude continuously and must be able to withstand 30 minute solar excursions and 90 minute deep space viewing at a minimum as stated in the Orbiter core ICD-2-19001. It is desirable to be able to withstand these extreme cases longer than the ICD requirement for manifesting reasons and longer runs are required for determining safety concerns such as the maximum design pressure (MDP) temperatures and battery limitations. The transient behavior of the experiment should be considered in all thermal analysis for the aforementioned cases.

2.2.3 Flammability Requirements for MLI Construction

Thermal control blankets are the most widely used materials in the payload bay that could be flammable. These blankets typically contain 12 to 40 layers of film (0.0005 to 0.002 inches in thickness) separated by some type of scrim cloth. Blanket materials are usually constructed of metal-coated polyethylene terephthalate or polyimide film, organic separator scrim, or beta cloth. Beta cloth and polyimides (at least 1.5 mil thick) are the only nonflammable materials.

Acceptable thermal control blankets are typically constructed as follows:

- a. The outer layer is made of nonflammable material such as a polyimide film (at least 1.5 mil thick,) metal foil, or beta cloth.
- b. Internal layers can be a combination of flammable films or scrims.
- c. The innermost layer (adjacent to the outer surface of the payload) is also made of nonflammable materials.
- d. Edges are hemmed or suitably finished so that the inner flammable layers are protected.

Reference: "Flammability Configuration Analysis for Spacecraft Applications" document NSTS 22648 dated October 1988.

2.2.4 Thermal System Design for a HH Canister

There are presently four options available to HH canister customers:

1. Fully insulated canister
2. Insulated canister without upper insulating end cap.
3. Uninsulated canister with lower insulating end cap.
4. Opening lid canister (uses insulated canister).

The first three options pertain to a sealed HH canister, while the fourth refers to the opening lid canister. The three canister insulation options for the sealed canister are intended to offer a wide range of heat rejection capabilities depending on customer requirements. GSFC provides all exterior thermal insulation and coatings for canisters except for the top surface of an HMDA customer payload. The temperatures listed for each orientation are approximate, and may vary somewhat (approx. +/- 10°C) depending on the Shuttle orbital attitude and beta angle (angle between the Shuttle orbit plane and the sun).

The first option, a fully insulated canister, would be the best choice for customers with relatively low power requirements. This option minimizes heater power needed to maintain operational temperature levels at cold Orbiter orientations. It does not, however, allow for large power dissipations on a continuous basis. Average steady-state canister upper endplate temperatures for various Shuttle attitudes and customer payload power levels is given in Figure 2.28. The temperatures from Figure 2.28 are representative of internal experiment temperature levels. The corresponding Orbiter attitudes are defined in Figure 2.29.

Option 2 offers an increased heat rejection capability over option 1, as shown in Figure 2.30. The canister top plate exterior surface is coated with silver teflon ($\alpha = .10$, $\epsilon = .75$) and acts as a radiator while the rest of the canister is insulated. Increased heater power, however, is required in order to maintain minimum temperature levels in cold Orbiter orientations. .

Option 3 is available to customers requiring a large heat rejection capability. In this case, the side walls of the canister are painted white ($\alpha = .24$, $\epsilon = .86$) and are allowed to radiate directly to the Shuttle bay and space. The average upper endplate temperature for various conditions is given in Figure 2.31. Power levels higher than those shown can be accommodated for short time periods depending on customer thermal design. However, large temperature gradients can be realized along with high power levels. Therefore, special attention should be given to the thermal design if Option 3 is selected. Also, large heater power levels are required to maintain minimum temperature levels even in the Earth viewing case if the experiment is operating at low levels. Transient response times are reduced as well.

Option 4 refers to the opening-lid canister. When the lid is closed, the canister thermal behavior is approximately the same as that of the fully insulated canister (Option 1). When open, thermal behavior is heavily dependent on the customer payload thermal design, especially the exposed upper portion of the instrument. It is suggested that customers using this option pay particular attention to their thermal design, due to the increased complexity resulting from the opening lid. Thermal information for customers with opening-lids can be found in "Thermal Design Guide for Get Away Special/Motorized Door Assembly Users."

Fully Insulated Canister (Option 1)

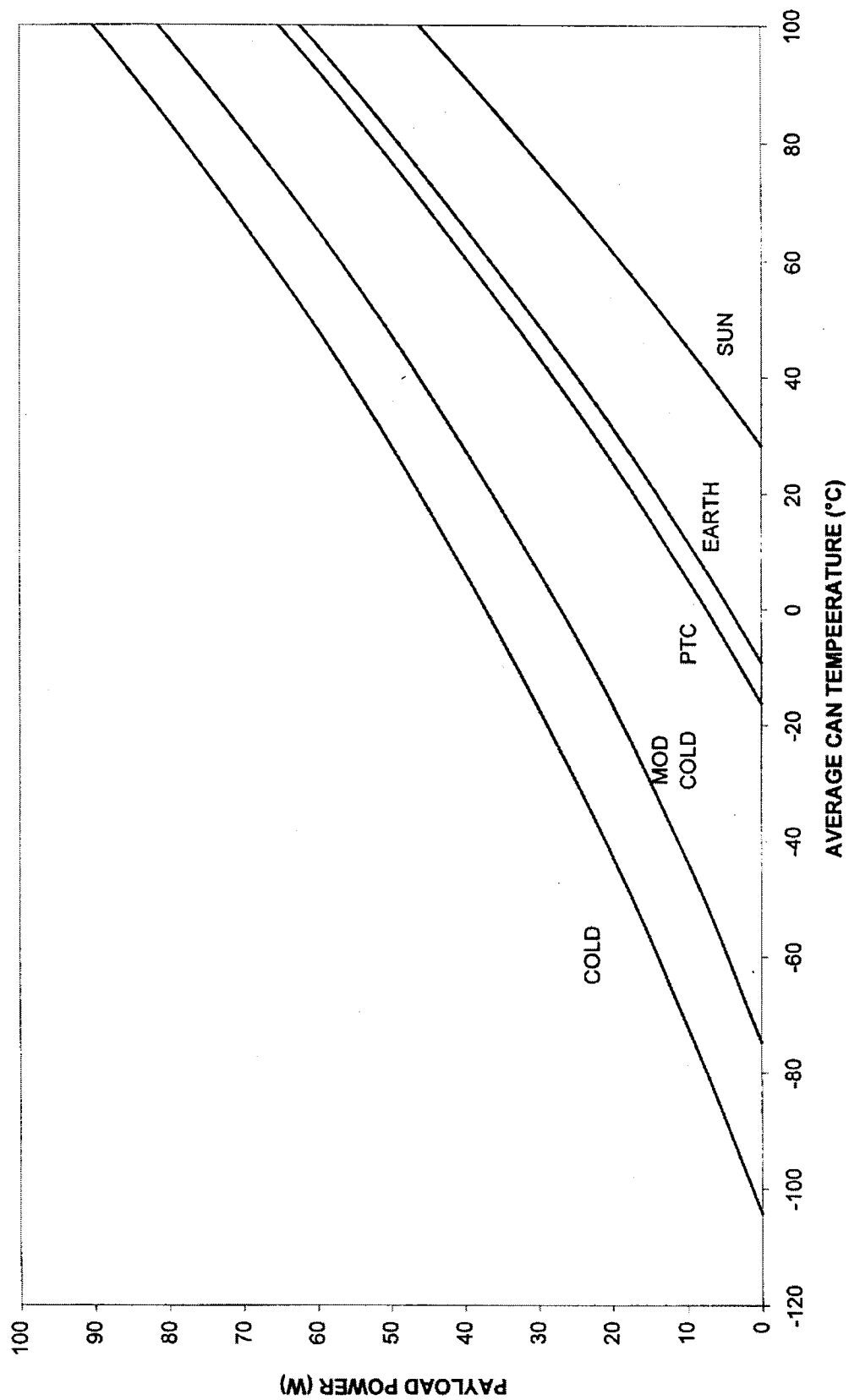


FIGURE 2.28 FULLY INSULATED CANISTER (OPTION1)

Typical Orbital Thermal Attitudes

(61% Sun, $B=35^\circ$, and Altitude = 150 n.mi. (278km.)

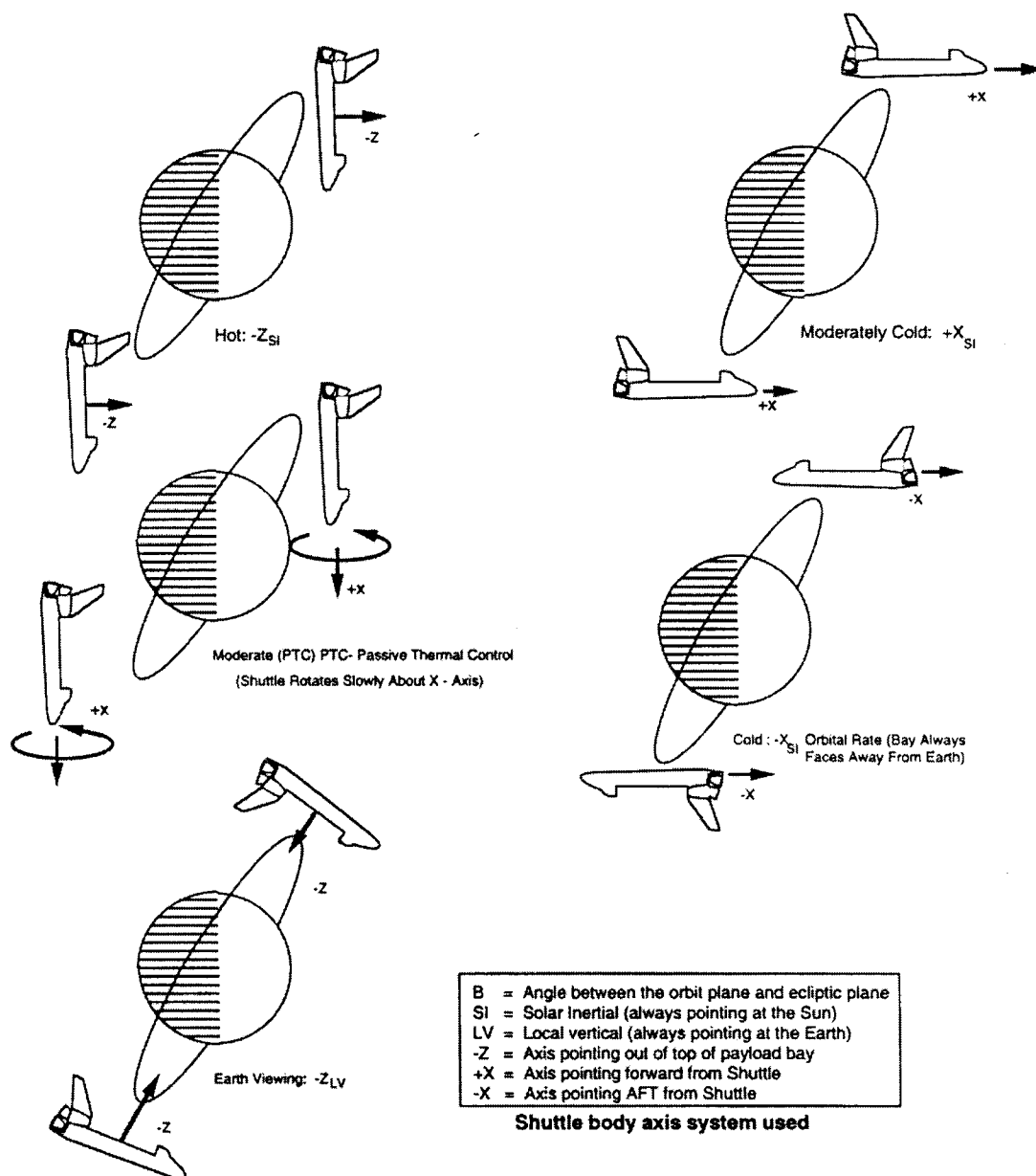


FIGURE 2.29 TYPICAL ORBITAL THERMAL ATTITUDES

Insulated Canister without Insulated Endcap (Option 2)

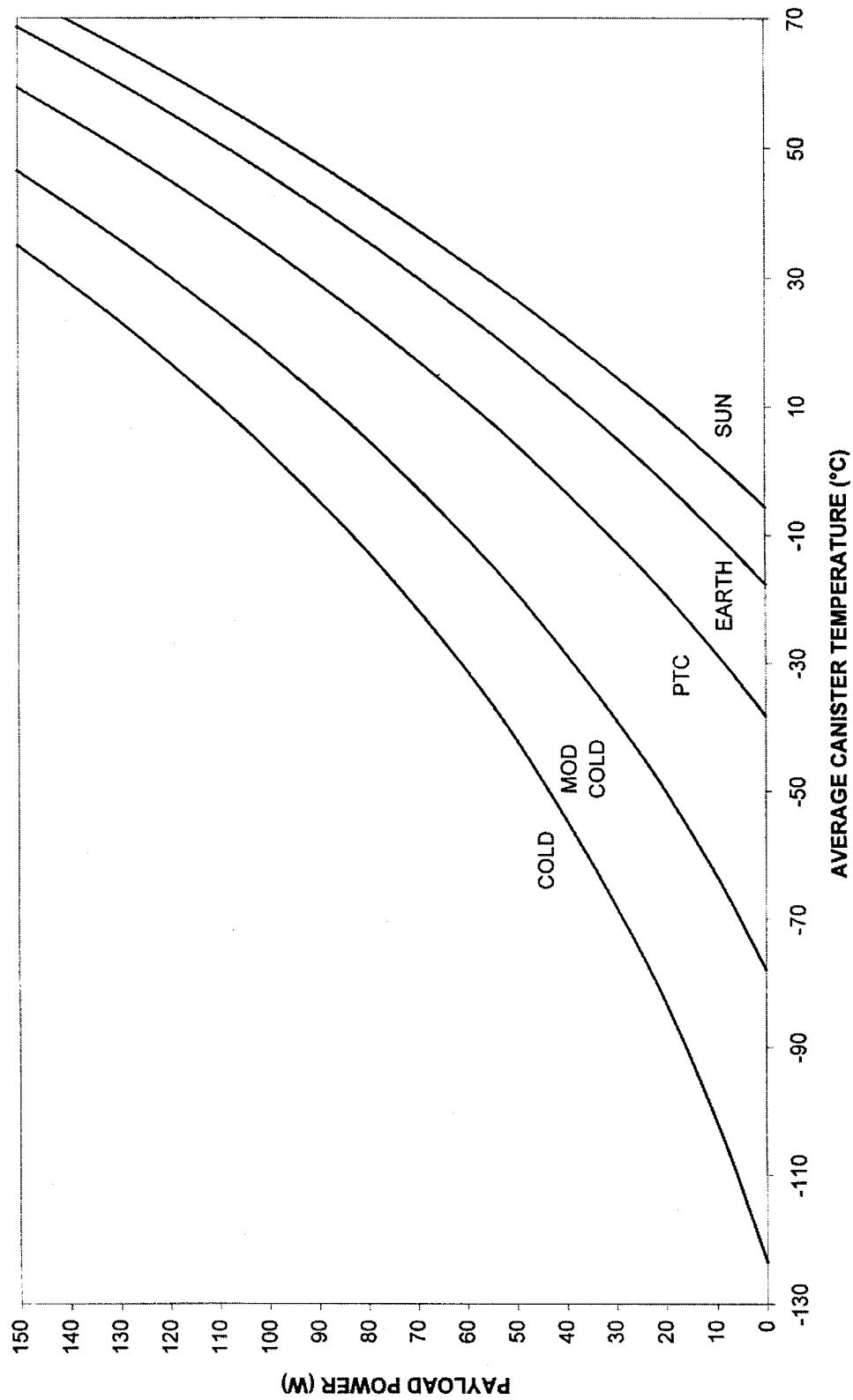


FIGURE 2.30 INSULATED CANISTER WITHOUT INSULATED ENDCAP (OPTION 2)

Uninsulated Canister (Option 3)

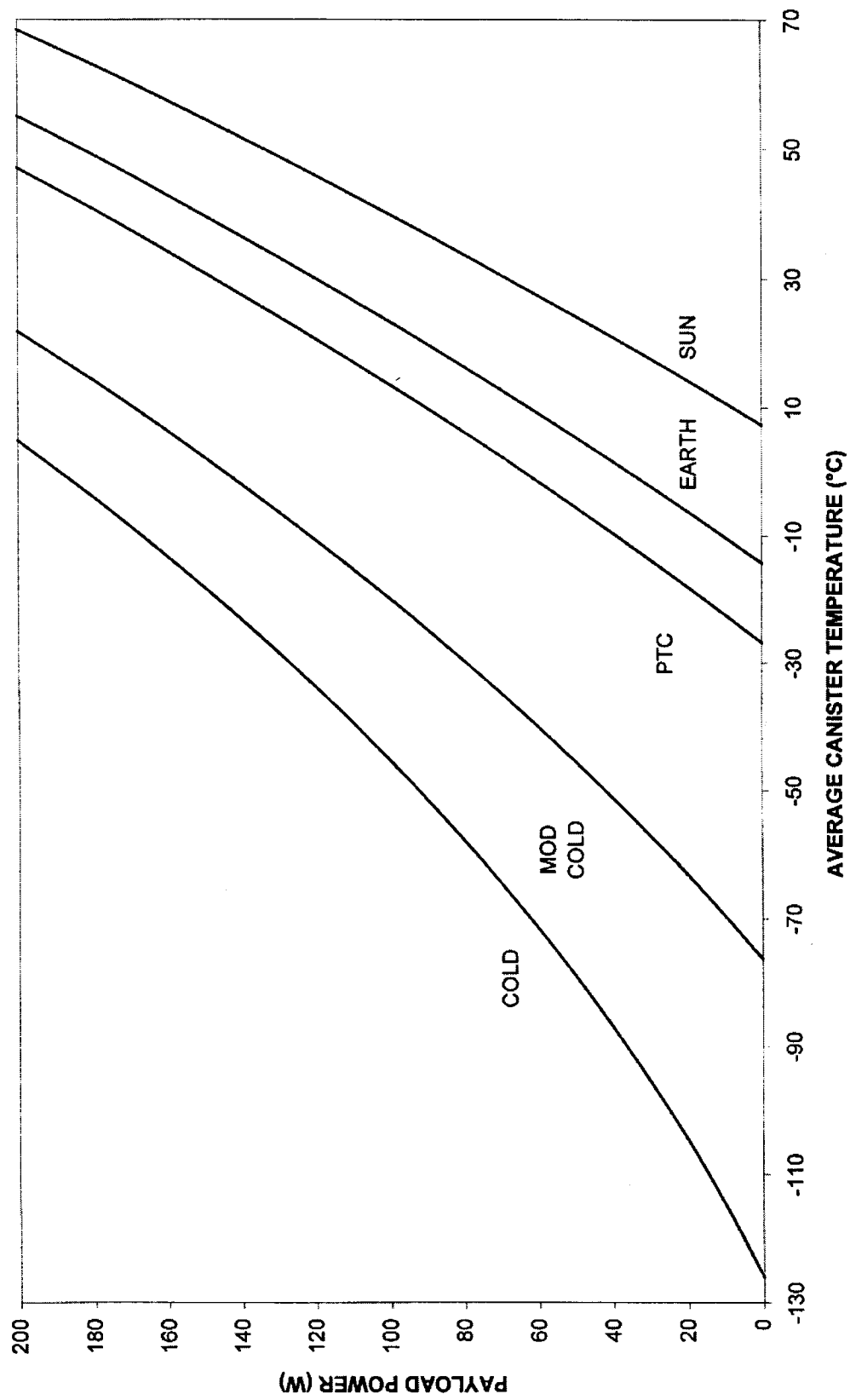


FIGURE 2.31 UNINSULATED CANISTER (OPTION 3)

Experimental data was obtained from the GAS Flight Verification Payload (FVP) on the flight of STS-3. Table 2.2 lists the steady-state temperature predictions and results for both hot and cold cases for the inside portion of the FVP. The experimental results are averages of thermistors or nodes at the indicated locations. The flight results listed are the hottest and coldest levels actually attained. They are not, however, the worst possible hot or cold case temperatures since steady-state conditions were not attained.

TABLE 2.2 CONTAINER AND PAYLOAD FLIGHT STEADY STATE THERMAL RESULTS

(Temperatures In °C) From Gas Verification Payload

<u>LOCATION</u>	<u>HOT CASE</u>		<u>COLD CASE</u>	
	<u>PREDICTED</u>	<u>ACTUAL</u>	<u>PREDICTED</u>	<u>ACTUAL</u>
Top Plate	48.0	32.0	-20.6	-2.5
Container Sides	49.2	32.0	-19.1	-3.0
Bottom Plate	49.9	34.0	-19.5	-3.0
Battery	52.3	31.0	-5.7	+1.0
Tape Recorder	52.9	35.0	0.0	+4.0
Power	13.0W	13.0W	34.0W	13.0W

Note: Actual flight thermal levels did not reach steady-state conditions. The levels are the maximum and minimum temperatures that were reached.

Table 2.3 shows external environmental thermal levels for steady-state conditions of the GAS container. It includes both predicted and actual flight thermal levels. Steady-state temperatures were not attained for the tail-to-sun, extreme cold case, which, therefore, is omitted from the table. The two predicted values for the adapter beam hot case correspond to two absorptivity values. The higher absorptivity value gives a better hot case correlation.

TABLE 2.3 GAS CONTAINER EXTERNAL THERMAL LEVELS AT STEADY STATE

	<u>PREDICTIONS °C</u>	<u>FLIGHT °C</u>
Adapter Beam (Hot-Bay to Sun)	+37 to +46	+45 to +50
Adapter Beam (Cold-Nose to Sun)	-78	-40
Bottom Cover (Hot-Bay to Sun)	+63	+63 to +65
Bottom Cover (Cold-Nose to Sun)	-76	-45 to -50
Top Cover (Bracket) (Hot-Bay to Sun)	+31	+25 to +35
Top Cover (Bracket) (Cold-Nose to Sun)	-73	-47 to -52

2.2.5 Thermal System Design for Pallet and Plate Mounting

The customer is responsible for the thermal design of a plate-mounted experiment system. This design will encompass the plate and its attachments to the GAS beam and Orbiter or to the HH bridge. Normally, in order to avoid problems with thermal/mechanical stress, a customer will want to provide good thermal conduction between his/her equipment and the HH mounting plate. On HH-S, the mounting plate has poor thermal conduction to the GAS beam. On HH-C, mounting plates are thermally isolated from the cross bay structure by means of special hardware which allows for thermal expansion. The HH-S GAS beam is attached to the Orbiter with hardware that also provides thermal isolation and allows for expansion.

GSFC will supply thermal model data on the HH plates and their attachments to customers. GSFC will also supply insulation for the backs of plates and white painted regions to cover the unoccupied front surface of plates. GSFC will supply a standard heater system on the back of the HH-S and HH-C small plate consisting of 104-watt heater and three thermistors. For the top of the bridge single and double bay pallets, GSFC will also supply 104 watts of heater power. (Thermostats on these plates open at 12 +/- 3 deg C and close at 6 +/- 3 deg C.) The customer may use this system by providing a cable to connect the thermal system to power from his customer port.

2.2.6 Thermistors

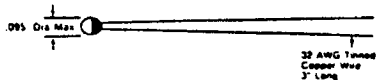
Three thermistors are available for each plate and pallet experiment. Opening can experiments have no thermistors except for one mounted on the lower endplate. Sealed canister experiments allow one thermistor to be used at the customer's discretion and one will be mounted on the lower end plate. Additional thermistors may be available through negotiation with the HH project.

These thermistors, Yellow Springs Instrument Company (YSI) 44006 type or equivalent (see the manufacturer's specification sheet on the following page), are supplied by the HH Project for connection to appropriate pins on J2, as outlined in Tables 2.4 and 2.5. This interface configuration allows monitoring of up to three temperatures when customer payload power is on or off. The thermistor interface between customer and carrier is shown in Figure 2.33.

YSI PRECISION THERMISTOR

YSI 44006

RESISTANCE 10,000 OHMS @25°C



RESISTANCE VERSUS TEMPERATURE -80° to +150°C	
TEMP °C RES	TEMP °C RES
150 10000	150 10000
140 10000	140 10000
130 10000	130 10000
120 10000	120 10000
110 10000	110 10000
100 10000	100 10000
90 10000	90 10000
80 10000	80 10000
70 10000	70 10000
60 10000	60 10000
50 10000	50 10000
40 10000	40 10000
30 10000	30 10000
20 10000	20 10000
10 10000	10 10000
0 10000	0 10000
-10 10000	-10 10000
-20 10000	-20 10000
-30 10000	-30 10000
-40 10000	-40 10000
-50 10000	-50 10000
-60 10000	-60 10000
-70 10000	-70 10000
-80 10000	-80 10000
-90 10000	-90 10000
-100 10000	-100 10000
-110 10000	-110 10000
-120 10000	-120 10000
-130 10000	-130 10000
-140 10000	-140 10000
-150 10000	-150 10000

Interchangeability: $\pm 0.2^\circ\text{C}$ (See Tolerance Curves).

Max. Operating Temp: 150°C (300°F).

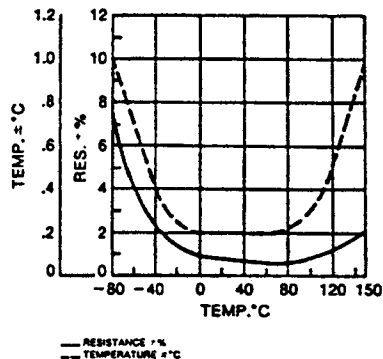
Time Constant, Max: 1 sec. in well stirred oil, 10 sec. in still air. Time constant is the time required for a thermistor to indicate 63% of a newly impressed temperature.

Dissipation Constant, Min: $8\text{mW}/^\circ\text{C}$ in well stirred oil, $1\text{mW}/^\circ\text{C}$ in still air. Dissipation constant is the power in milliwatts to raise a thermistor 1°C above surrounding temperature.

Color Code: Black epoxy body, blue end.

Storage Temperature: -80° to $+120^\circ\text{C}$ (-112° to $+250^\circ\text{F}$).

Tolerance Curves: The following curves indicate conformance to standard resistance temperature values as a % of resistance, and as a maximum interchangeability error expressed as temperature.



WARNING

Use heat sinks when soldering or welding to thermistor leads.

FIGURE 2.32 YSI PRECISION THERMISTOR

Thermistor Interface to Carrier

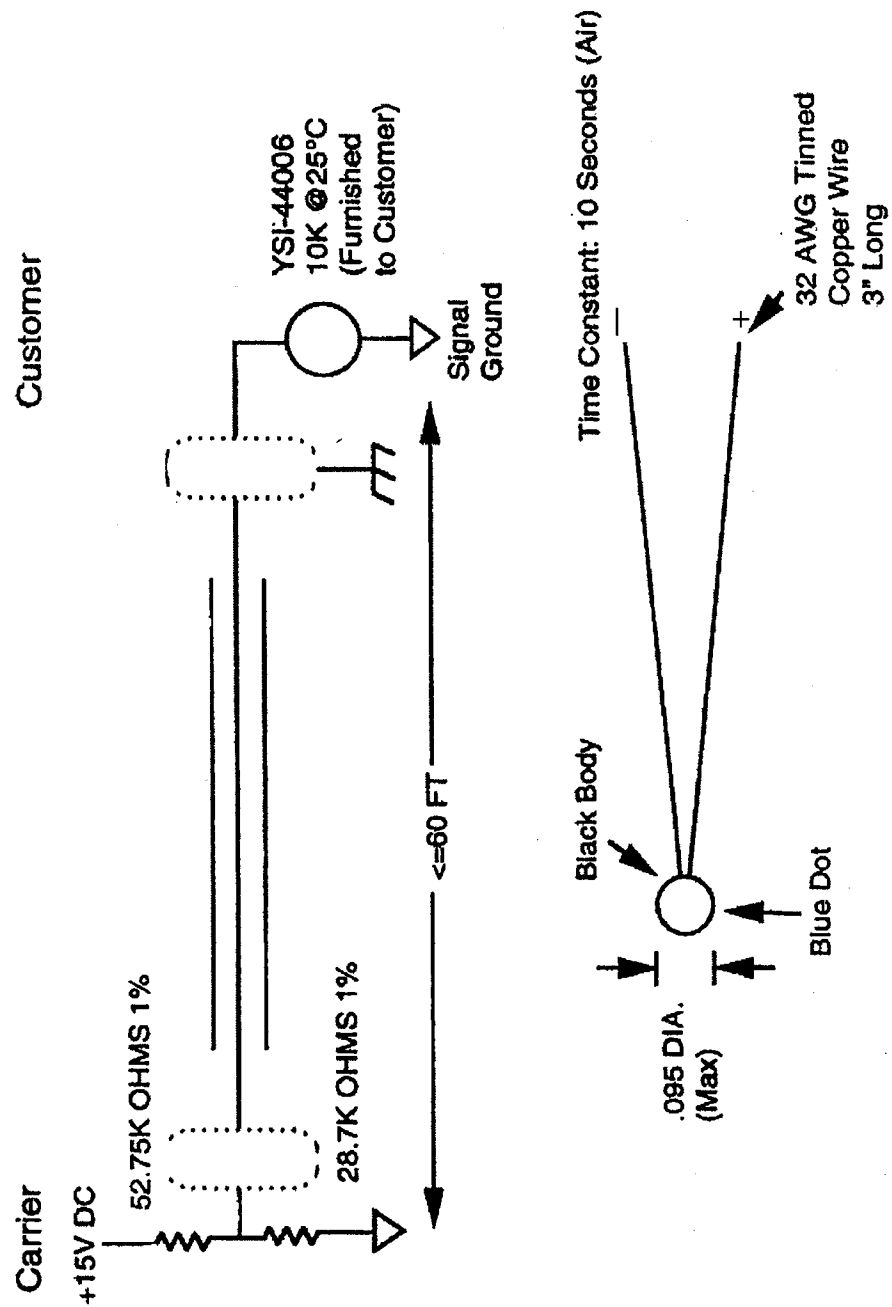


FIGURE 2.33 THERMISTOR INTERFACE TO CARRIER